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AD-P003 945	The Application of Artificial Intelligence to a Maintenance and Diagnostic Information System.
AD-P003 946	Intelligence Information Retrieval from on-Line Technical Documentation.
AD-P003 947	On the Requirements of Expert Systens for Fault Isolation.

Expert Systems in Maintenance Diagnostics for Self-Repair of Digital Flight Control Systems

John Davison
Air Force Flight Dynamics Laboratory

A couple of weeks ago, the Flight Dynamics Laboratory (FDL) of Wright-Patterson Air Force Base met with our sister laboratory, the Avionics Laboratory, to exchange some ideas on artificial intelligence. I briefed them on this workshop program and they were surprised to learn that FDL was going to demonstrate a maintenance diagnostics system this spring. They had not planned to do this until 1987. They suggested that I contact Dr. Richardson and this workshop and communicate some of these ideas as they think this demonstration is a well kept secret of the work we've been doing. However, I might add that we've been too busy working to advertise.

discusses

I'd like to cover three basic components of this program. One is an overview and the progress of the program starting off with the battle damage statistics that are supplied to us by aircraft battle damage repair people. These statistics are the drivers that influence the self-repairing program. They are gathered primarily from Southeast Asian data, updated from the Falklands conflict and Israeli data. Secondly, ~~I would like~~ to ~~talk~~ briefly about the self-repairing concept, and thirdly, the status of our expert system for maintenance diagnostics.

Figure 1 assumes a four-to-one damage/loss ratio for a status of the fleets during surge. The dramatic part about the top line is that after the second day, as you can see, 68 percent of all the aircraft are out of commission. That's not due to attrition alone; we have aircraft that are awaiting maintenance and in battle damage repair. Those are pretty alarming statistics.

If we examine aircraft losses by functional area, we see that flight control is a large contributor along with fuel and fire explosion and propulsion system. In aircraft damages by functional area of the return, flight control is again a large contributor, around 18 percent. However, when we look at the percentages of the aircraft returning with damage (see Figure 2), propulsion, fuel, power, and, of course, structural damage are the real drivers. I don't know why structure isn't 100 percent, I think everything has to go through the structure. I think this graph was based on small arms fire only. When we look at the repair time it takes to turn the plane around, we see that flight control occupies the majority of the median time to repair. Figure 3 shows that even with the advent of digital electronics and the complexity of the flight control systems, we're still only at 11 percent of the cost in the digital electronics. The drivers are still in the equipment areas, for example, in the servos.

As you'll see in Figure 4, the self-repairing system is broken into three general areas. The first is the survivability of the aircraft where we're concerned with real-time configuration in case of system faults and battle damage where we reconstruct the forces and moments using the remaining surfaces. For the quick

STATUS OF FLEET DURING SURGE

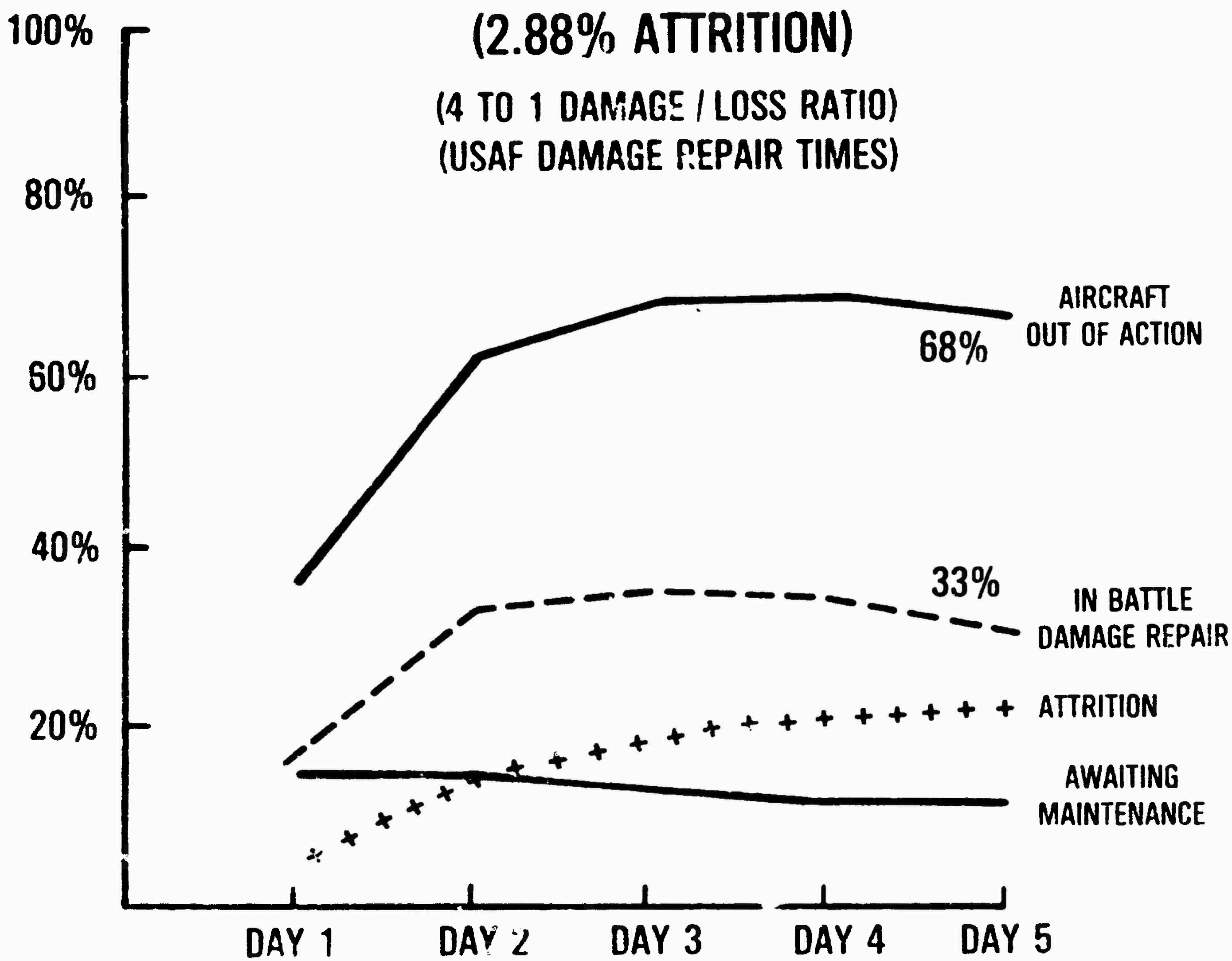


Figure 1.

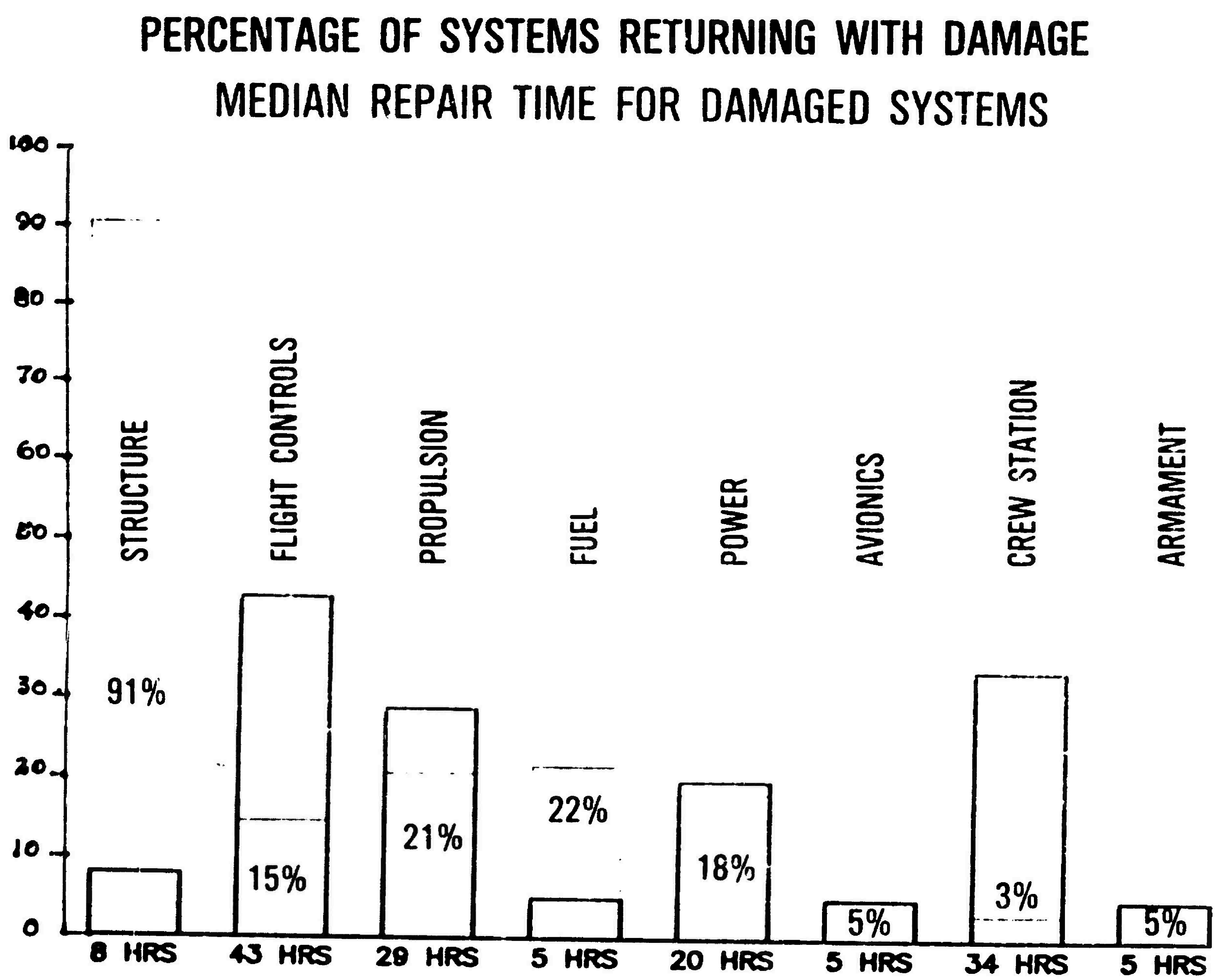

PERCENTAGE OF SYSTEMS RETURNING WITH DAMAGE
MEDIAN REPAIR TIME FOR DAMAGED SYSTEMS
100
90
80
70
60
50
40
30
20
10
0
STRUCTURE
FLIGHT CONTROLS
PROPULSION
FUEL
POWER
AVIONICS
CREW STATION
ARMAMENT
91%
15%
21%
22%
18%
5%
3%
5%
8 HRS
43 HRS
28 HRS
5 HRS
20 HRS
5 HRS
34 HRS
5 HRS

Figure 2.

FCS COST PROFILE
DIGITAL FBW

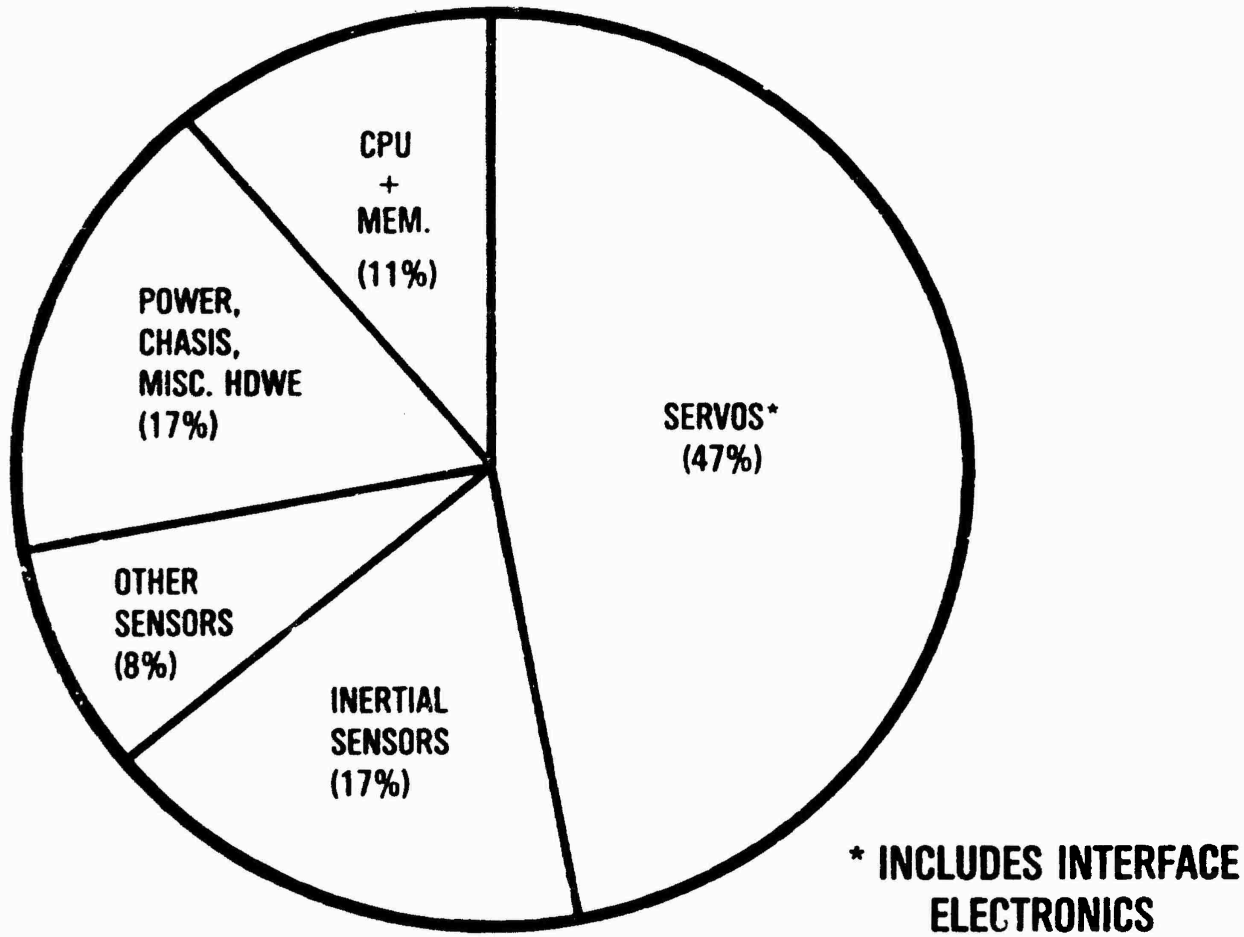


Figure 3.

SELF-REPAIRING DIGITAL FLIGHT CONTROL SYSTEM

SELF-REPAIRING SYSTEM

SUSTAIN ACCEPTABLE AIRCRAFT PERFORMANCE FOR EXPANDED ARRAY OF BATTLE DAMAGE STATES OR SYSTEM FAULTS

GET HOME

RECONFIGURE REMAINING CONTROL SURFACES TO RECONSTRUCT CONTROL MOMENTS & FORCES

QUICK TURN-AROUND

AUTOMATE MAINTENANCE DIAGNOSTICS

EXPERT SYSTEMS

PERFORM MISSION

AUTOMATE PILOT ASSESSMENT FOR REMAINING CAPABILITY & PROBABILITY OF MISSION SUCCESS

Figure 4.

turn around of the aircraft, we're looking at automatic maintenance diagnostics and we're using an application of expert systems. Because we can detect and classify these failures, we want to let the pilot know what capability remains, not just what has failed.

To take a general look at our system in a single channel, the blocks in solid lines in Figure 5 would be a standard flight control system. The key in this system is our system impairment detection classification function. This feeds into a drop-in module where we remix the flight control laws and send them back to the flight control computer without changing those flight control laws at all. As long as we're able to do that, as I mentioned, we give the pilots a real-time status of what are the operational capabilities. For example, we might tell them that with the remaining capability they can only pull 4½ G's as opposed to 6½.

In our maintenance diagnostics, we think that we're going to follow the TAC two-level maintenance concept so that we can data-link figures back to the forward base. If the pilot has a servo that has failed or experienced damage, the mechanic will be waiting with a part at hand as the plane taxis up. However, it's really not our idea that maintenance begins in the air. Other people have been doing it for a long time. We do think that we have a little different approach to the problem, though. This is where we get into our maintenance diagnostics computer. In our approach, the troubleshooting expert is paramount. We're also going to use in-flight faults, the situation data, and we're going to incorporate the technical orders and the illustrated parts breakdown in our maintenance diagnostics computer.

The general components of the expert system are the same. As you'll see in Figure 6, in the knowledge base we use the heuristics and the rules of logic and in the situation base we use current data, historical facts, and background information. That's also where we put all our flat file data for all the prioritized possible faults. It goes directly into our maintenance computer, and that computer interrogates the maintenance person. For example, we're experiencing in-flight faults and, let's say we had a problem in the pitch axis, it would drop us right into the pitch axis diagnostics. Part way through the diagnostics the computer may ask maintenance if the follow-up potentiometer in the pitch actuator has been checked. If the maintenance person punches the "no" button, the next question would be, "Do you know where it's at?" If the "no" button gets punched again, we bring up the illustrated parts breakdown technical order file and draw a tone over the follow-up pot to indicate exactly where it's located. Then we explain how to go about checking that and clear the system.

We're looking at two possible applications. For new applications, we'd like the computer to be autonomous and reside in aircraft. Right now, we're trying to impact existing aircraft like the F-15 and the F-16 (Figure 7).

Question: I have a problem: Why would you do that when it's sent in subject to battle damage?

Davison: It can be stand-alone, or because it is stand-alone, we can roll another one up in front if it does have battle damage. But we don't want to get into the redundancy, triplex and quad of everything in airplanes. It can be easily substituted.

SELF-REPAIRING FLIGHT CONTROL SYSTEM

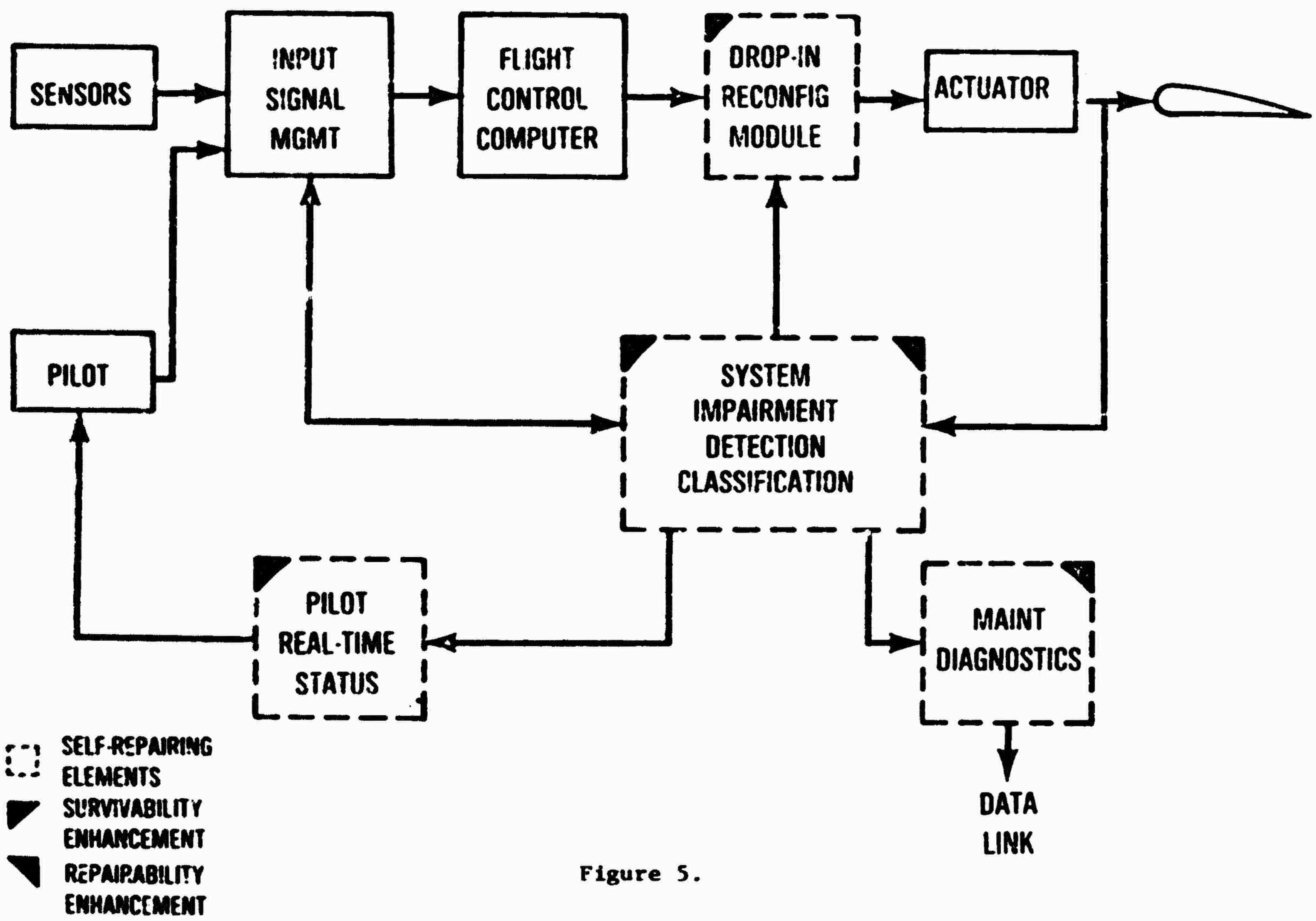


Figure 5.

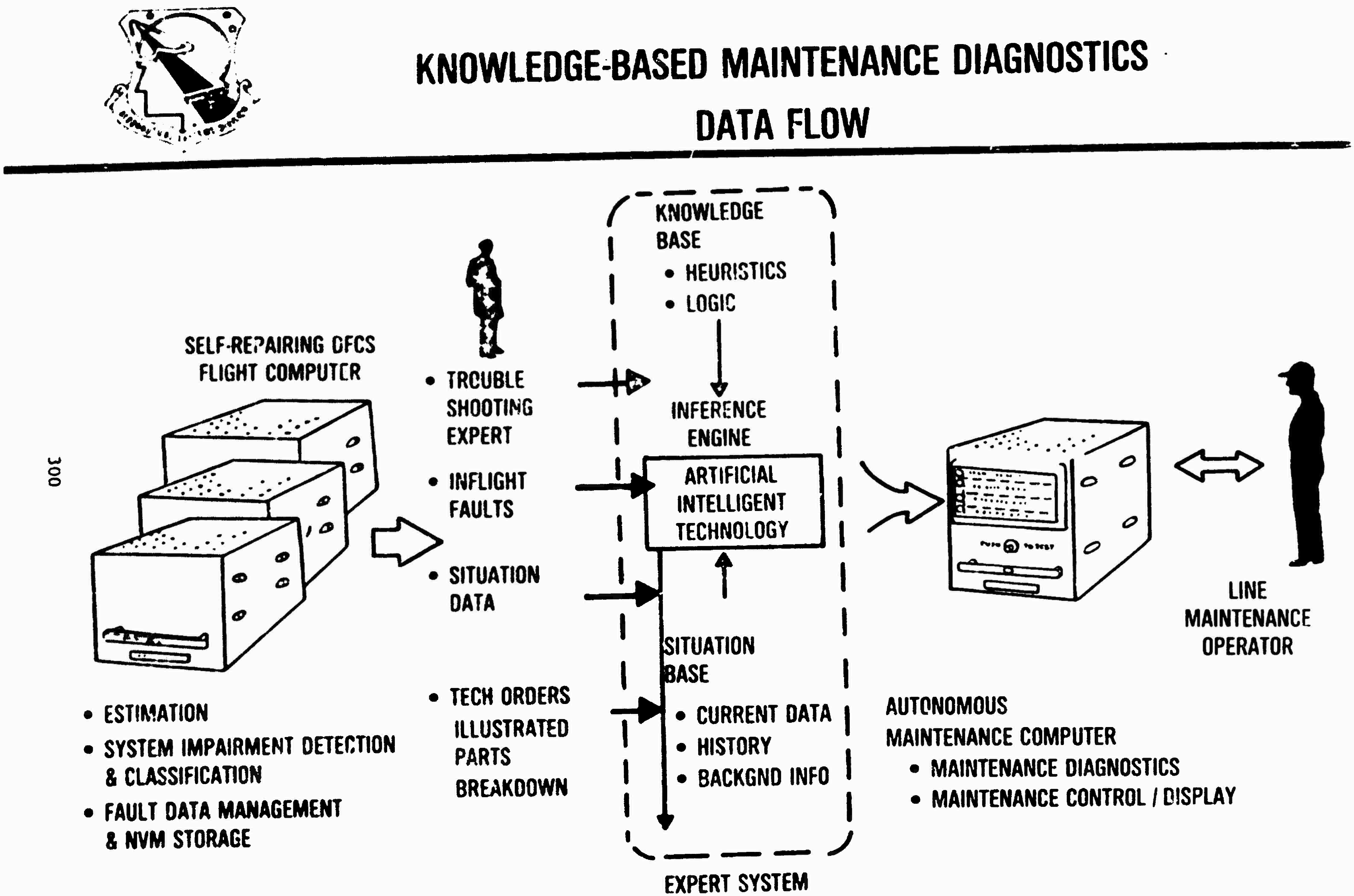
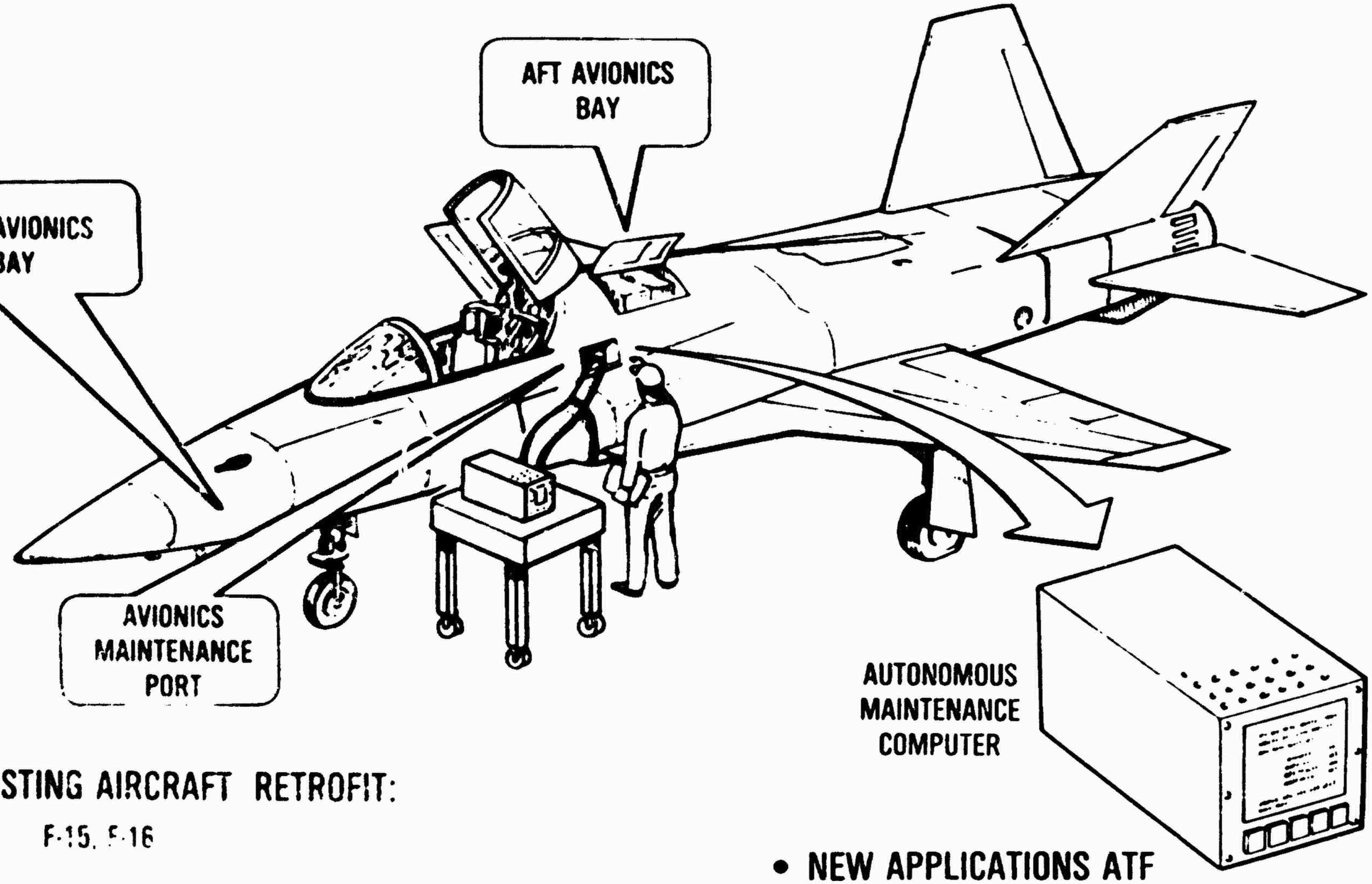

KNOWLEDGE-BASED MAINTENANCE DIAGNOSTICS
DATA FLOW
SELF-REPAIRING DFCS
FLIGHT COMPUTER
• ESTIMATION
• SYSTEM IMPAIRMENT DETECTION & CLASSIFICATION
• FAULT DATA MANAGEMENT & NVM STORAGE
• TROUBLE SHOOTING EXPERT
• INFLIGHT FAULTS
• SITUATION DATA
• TECH ORDERS ILLUSTRATED PARTS BREAKDOWN
KNOWLEDGE BASE
• HEURISTICS
• LOGIC
INFERENCE ENGINE
ARTIFICIAL INTELLIGENT TECHNOLOGY
SITUATION BASE
• CURRENT DATA
• HISTORY
• BACKGND INFO
EXPERT SYSTEM
AUTONOMOUS
MAINTENANCE COMPUTER
• MAINTENANCE DIAGNOSTICS
• MAINTENANCE CONTROL / DISPLAY
LINE
MAINTENANCE
OPERATOR

Figure 6.

SELF-REPAIRING DIGITAL FLIGHT CONTROL SYSTEM



- EXISTING AIRCRAFT RETROFIT:
  F-15, F-16
- NEW APPLICATIONS ATF

Figure 7.

I heard a lot of conversation this morning about the quality of maintenance personnel and the problems involved with troubleshooting the system. Let me tell you that flight control systems are complex. There's digital, quad, fly-by-wire systems, and I don't care if you're a control engineer or a mechanic, when you open up that panel and try to troubleshoot that system, it's like a hog looking at a wristwatch. I mean, you don't know where to begin. We think this self-repairing system is the only way we can circumvent that problem.

We think we're really a little bit ahead of the game because we've relied on General Electric and have a contract with them to develop this system. We're riding on the coattails of their DELTA system, the locomotive system for maintenance diagnostics. This is supported with both Air Force funds and IR&D funds. In order to develop their DELTA system, it took them 12 months to get a 50 rule feasibility demo model. It took another year to bring it into lab prototype and a third year to a field prototype model--that's at around 500 rules. To get into a 1200 rule system, it's 4 years and about a megabyte of memory.

Figure 8 shows where we are right now. We're going to use the F-18 because it's the only production digital fly-by-wire system available now. We're going to develop a 50 rule system and demonstrate this in the coming spring. We're moving this technology into our AFTIF-16 and by March of 1986, we hope to have a 1200 rule system developed and in place.

To wind this up, we want to look at both the on-board diagnostics and be able to data link this data back to the forward base. This will provide rapid assessment of fault and damage. We want to incorporate all the technical orders into the flight hardware. We want to impact that median repair time of 43 hours (rf. Figure 2) and reduce it by a factor of five. By incorporating those technical orders in there, we eliminate a ground-support function, so we don't have to divert to the large fixed infrastructure-type bases. We can divert anywhere, the maintenance people can rendezvous with the airplane and hopefully perform maintenance that would normally be performed at the depot level.

Question: I don't understand why you call it self-repairing?

Davison: Well, we're reconfiguring the flight control laws. Regarding self-repairing, we're talking about the system level. We're not using artificial intelligence to reconfigure the system; that's another presentation.

Question: Doesn't the maintenance person still make the replacement?

Davison: Yes, but we're saying that we can do away with the unscheduled maintenance and continue to fly by being able to detect, isolate, and recover from any failure in the system.

Thank you.

SELF-REPAIRING DIGITAL FLIGHT CONTROL SYSTEMS

EXPERT SYSTEM DEVELOPMENT SCHEDULE

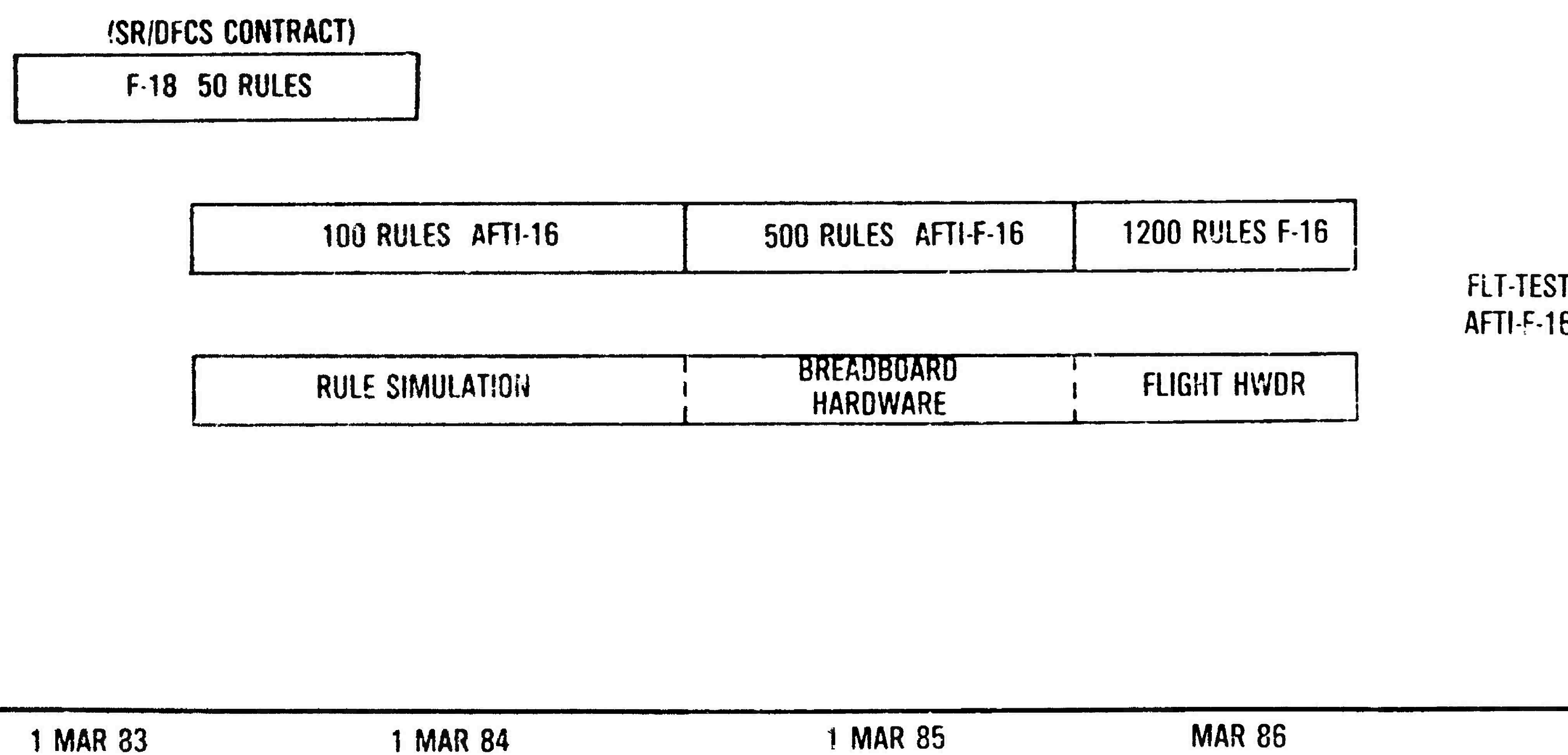


Figure 8.

ABOUT THE AUTHOR

John W. Davison is a Project Engineer in the Flight Control Division of the Air Force Wright Aeronautical Laboratories Flight Dynamics Laboratory. He is responsible for project planning and technical management of R&D programs dealing with flight control system reliability and safety. During the mid-1970s, Mr. Davison served as lead engineer for reliability and safety analyses of the Laboratory's C-141 All Weather Landing System flight demonstrator. He was subsequently instrumental in focusing emphasis on the need for development of software reliability prediction methods. He currently directs laboratory activities in self-repairing flight control, a concept involving in-flight reconfiguration and advanced maintenance diagnostics based on expert system concepts.